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CONTENTS

	PAGE
Compost and Disease	21
Toxicity of D.D.T. to the Housefly	23
Review: Farming and Gardening for Health or Disease	24
The Preparation of Refined Rice Bran ...	25
Effect of Depth and Fluctuations of Water-Table on the Growth of Sugar Cane ...	29
The African Oil Palm	30
Soil Microbiology as a Field of Science ...	31
Miscellaneous Notes	35
Chemical Notes	36

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COMPOST AND DISEASE

MUCH publicity has been given lately to the subject of compost. The attention of readers is drawn to a paper (1) read by Dr. V. A. Wager at the nineteenth annual congress of the South African sugar technologists' association, to a review published elsewhere in this issue on Sir Albert Howard's latest book on "Farming and gardening for health or disease", and to an article (2) by Dr. H. M. Leake entitled "The foundation of agriculture" which is inspired by Sir Albert Howard's book and which appeared in a recent issue of *The International Sugar Journal.*

Although Dr. Wager agrees that compost is one of the best known promoters of vigorous plant growth and that every agriculturist should be induced to use it, he deplores the fact that in popular articles on the subject statements are repeatedly made that vegetables grown on compost will not be subject to plant diseases or insect pests, and that animals or humans fed on such compost-produced plants or vegetables will in turn also avoid all manner of illnesses or ailments. King (3), for instance, says "As the fertility of our soil is built up (with compost), pests and diseases disappear because, once the soil is fertile, the crops protect themselves ..... I believe compost is a certain cure for all diseases of tomatoes ..... if healthy plants are secured and compost is used ..... total immunity from disease can easily be obtained." According to C. A. Baker (4) ".... A healthy soil gives no encouragement to disease in animals or plants and does not bring forth insect pests ..... the addition of mineral fertilizers to the soil decreases plant resistance to disease." Balfour (5) says "..... If the fertility of the soil is built up with adequate supplies of humus, crops do not suffer from disease and do not require poison sprays to control parasites ..... animals ..... and man ..... fed on these plants develop a high degree of disease resistance." Finally Howard (6) states

1. Wager, V. A. (1945).—Compost and disease. *Proceedings of 19th Congress of the South Afric. sug. techn. assoc.*
2. Leake, H. M. (1945).—The foundation of agriculture. *Int. Sug. Jr.* **47**, 287-289.
3. King, F. C. (1943).—The compost garden.
4. Baker, C. A. (1942).—The labouring earth. *Heath Cranton, Ltd.*
5. Balfour, E. B. (1937).—The living soil. *Faber and Faber, Ltd.*
6. Howard, Sir Albert (1940).—An agricultural testament. *Oxford Un. Press.*

"Resistance to insect and fungus diseases is conferred by humus . . . . . The policy of protecting crops from pests by means of sprays, powders and so forth is unscientific and unsound . . . . There can be no doubt that the work in progress on disease at the experiment stations is a gigantic and expensive failure."

"It may well be, of course" says Dr. Wager, "that such statements are made with tongue in cheek, as propaganda, to provoke argument, or to stir the imagination of the more gullible farmers or backyard gardeners, and thus give more publicity to the main theme, which is, commendably, "Use more compost." But actually, no good can come of publicising false statements and thereby alienating the interest of scientists or the sympathy of progressive farmers. For compost is not the panacea of all ills and it is no good saying so."

Dr. Wager shows that some diseases of the animal and plant kingdom are primarily due to malnutrition and adverse conditions and could admittedly be prevented and perhaps be cured by taking steps that would promote vigorous growth. There definitely exist, however, organisms which are the primary cause of disease and which will attack animals and plants irrespective of their state of health. Tuberculosis, for instance, is a disease which is much more prevalent in the poorer and undernourished strata of the population and a definite correlation here can be established between the health and vigour of the person and susceptibility to disease. Influenza and malaria, on the other hand, are no respecters of persons, and, in the case of the latter, a hungry mosquito seems quite indifferent to whether his victim is robust or suffering from malnutrition. Then again, many people are "carriers" of disease and as such do not suffer any ill effects from the presence of the parasite or have become immune. Typhoid, and malaria in Northern Zululand among natives, are given as examples. In the case of nagana disease in cattle "most of the game animals in affected areas have the trypanosomes in their blood but are not affected by the disease. When cattle are brought into the area, however, they almost immediately contract the disease through being bitten by the carrier, the tsetse fly, and mortality is high. Yet the cattle and game both feed off the same non-composted veld."

In the realm of plants there are many diseases produced by fungi or bacteria which occur when the plant is in an unhealthy or weakened condition due to some cultural, soil or climatic fault. Gummosis of citrus, die-back of avocado and root-rot of papaws are all examples of such diseases. In gummosis, for instance, the fungus is present in the soil of most orchards and if the tree is growing under healthy conditions it will not harm it. As soon, however, as unfavourable conditions arise,—and in this case it is too much rainfall or irrigation leading to a temporary waterlogging of the soil—then the fungus will immediately attack the base of the trunk, causing excessive gum production, killing first the bark and finally the tree.

Weather conditions are also the direct cause of many plant diseases. The spores of some fungi or bacteria are not harmed by being dried and can therefore be carried over long distances in the air by winds or dust storms. In others, the spores must always be kept wet and so require rain storms or splashing for their dissemination. Thus, a sudden change in weather may either bring on a disease in epidemic form or it may cause it to disappear, and all the infected plants may recover. Late blight in potatoes is a good example of this. Following a rain storm the disease will develop with such amazing rapidity in a potato field that within a week all the plants are brown and dead. The condition of the plant does not make the slightest difference, for healthy or weak, the fungus will infect the leaves and destroy them all. The same is true of a disease like witches' broom of cacao which will attack a tree whether it is healthy or not. Dr. Wager shows in his paper how he failed to control bacterial wilt of tomatoes and eelworm by growing the plants in compost. He also mentions that resistant varieties of plants will grow successfully in non-composted soil, a case in point being the bacterial wilt resistant egg-plant "Kopek" which will grow well without compost whereas the common, non-resistant variety, growing alongside will die of wilt.

It is clear that, although there are diseases to which plants are more susceptible when undernourished, there are other diseases which they can get just as readily whatever their state of health may be and whether they have been fertilized with compost or not. It is true that there is ample evidence of the beneficial effect of compost on plant growth, but there are no indications, nor is there any statistical or material proof, that compost will confer immunity to disease. The main theme of Dr. Wager's paper is a refutation of some of the wild claims made by compost enthusiasts and especially the claim that compost confers some property on plants which makes them immune to attacks from pests and diseases. On that account Dr. Wager's paper is of great value in that it has exposed some of the fallacies about compost and its relationship to disease.

The most reasonable and yet questionable argument advanced by users of compost, however, is not that the plant will become immune from disease but rather that continual composting, by restoring a soil to its original virgin state of health will eliminate the sources of disease. As Dr. Leake points out in his article "The obvious dependence of the plant on supplies of certain elements in inorganic form from solution in the soil moisture has masked the more subtle source of nourishment. There is a mounting volume of evidence that it is the mycorrhizal association which renders that latter source available to the plant, and the

mycorrhiza, itself a living organism, feeds on the products of decomposition and constitutes a stage in the descending cycle of the wheel of life. Anything which interrupts this circulation of organic matter must sooner or later lead to disaster, and that is exactly what man has done. Nature, in the course of ages, has built up large reserves of partly decomposed matter, the humus of the soil, uses it as capital to draw on and later makes good the withdrawal; man has intervened, has drawn on the capital but failed to replace the withdrawal, substituting the incinerator and the modern methods of sewage disposal."

"... It is the biological aspect of the soil which is all-important and humus forms the source of energy for that activity. But humus is not the only necessity. The biological activities of the soil and especially mycorrhizal development, require aerobic conditions which accompany good tilth, and the basis of good tilth is the compound soil particle. Here humus plays its second important if indirect rôle, for it is humus which supplies the cement of the compound particle. The effects of the breakdown of the compound particle are many; lack of aeration is only one. In the process of time a pan forms below the surface which isolates the soil, checking the movement of soil moisture; with it, the flow of plant food in solution is checked and the plant is compelled to subsist on the surface layers. Ill-health results and, with it, disease; for the anaerobic conditions established are beloved of such pests as eel worm. Under such conditions, the direct supply of plant food in inorganic form is merely a palliative, for it remedies only one of the adverse conditions."

"It is unfortunate that as the fight between these new and the old-established ideas has developed, it has taken the form of humus *versus* artificials. It is difficult to prove a negative; to prove that adequate humus combined with the breaking up of the hard pan will eliminate disease entirely and will under all conditions place adequate inorganic plant food at the disposal of the crop. Anything which renders the plant unhealthy will create a disposition to disease, and a plant will not remain healthy if grown under conditions approximating to the marginal environmental requirements of the particular species or variety and agriculture offers many examples of attempts to grow plants under such conditions. But the general inference is clear. Artificials are the most effective man-made method of destroying the compound particle and developing conditions which lead to ill-health with consequent disease."

"That is the argument, but it does not stand alone. It is supported by a wealth of evidence, drawn from practical experience from all over the globe, which is convincing to the impartial mind. And it is evidence which covers the whole range of organic life; the healthy soil leads to the healthy, disease-free plant, to the healthy disease-free animal and finally, to the healthy disease-free man. It is true that much of this evidence is derived from the experience of the practical man and lacks the scientific foundation which it has become customary to demand in such matters ..."

The information submitted in both Dr. Wager's and Dr. Leake's articles only point to one thing—the great need for much more scientific evidence on the effect of compost on the soil and on the growth of plants. It will not be until this evidence is forthcoming that the true value of compost can really be assessed and to discuss its merits and demerits in the scheme of agriculture can at present only be a matter of conjecture. As Dr. Crowther of Rothamsted points out "Nothing is to be gained by treating composting as a universal panacea. The enthusiasts who support their propaganda for some special ritual, by attacking the use of fertilizers, would be doing a great disservice to our present food production programme, if, in fact, notice were taken of them outside the popular press. I do not think that anything can usefully be said on present evidence about those hypothetical ingredients of compost which have been said to confer perfect health and immunity from all diseases on plants, animals and man".

TOXICITY OF D.D.T. TO THE HOUSEFLY

During the War the importance of the compound usually referred to as D.D.T. as an insecticide has been demonstrated. In the *Bulletin of Entomological Research* **36**, Pt. 2; Sept. 1945, E. A. Parkin and A. A. Green, of the Pest Infestation Laboratory at Slough, describe experiments in testing the efficacy of controlling the housefly (*Musca domestica*) by means of D.D.T. They found that when applied as a spray containing 0.1 per cent. w./v. or more of D.D.T. in kerosene it is very toxic to the insect in question. At 1 per cent. strength D.D.T. gives an effective spray for practical use but at lower concentrations its action is too slow. Its advantages as a fly spray are that it can be prepared synthetically; it is almost odourless; it will not stain fabrics, &c.; it appears to have no marked irritant effect upon the operators up to 2 per cent. strength; it is extremely lethal to flies both in solution and in the solid form after deposition on walls, &c., from volatile solvents. Its main disadvantage is its slow rate of action on flies unless used at a concentration of at least 1 per cent. w./v.; but, even at this strength, affected flies produce an unwelcome buzzing, for at least an hour prior to the wing muscles becoming paralysed. The slow action of this compound can be overcome by the admixture with D.D.T. of a small amount of pyrethrins which has a very rapid paralytic effect. It would appear that the two constituents act independently, the rapid effect of the pyrethrins keeping the flies immobile until the slow lethal action of the D.D.T. has had time to come into effect.—(*Nature*, **156**, 3973, 745, 1946).

REVIEW

FARMING AND GARDENING FOR HEALTH OR DISEASE

By Sir Albert Howard assisted by Louise E. Howard.

Faber & Faber Ltd., London, 1945, pp. 282+15 plates, 12*s.* 6*d. net.*

IN this book Sir Albert Howard has elaborated his ideas on the control of pests and diseases of plants and animals, which he had previously stated in "An Agricultural Testament." In brief, his main thesis is that if soils are manured with well made compost, and not with artificials, there will be copious mycorrhizal formation and the crops will be vigorous, fruitful and free from diseases and pests. Moreover, both man and animals, when fed on the produce of fertile soils, manured with compost, will be healthy and resistant to disease. On the other hand, where only artificial manures are used, the soils will be "poisoned", the crops unhealthy and liable to the attacks of insect pests and diseases, so that chemical sprays are much in evidence; furthermore, such crops will be inferior in quality and will not confer the same disease resistance to the stock or people who consume them. This is a very plausible theory but unfortunately, if we examine it step by step, we find that the whole structure is built up on half-truths and generalisations. It is the plausibility of the whole story, in which a great deal of sheer wishful thinking is mingled with sound observations based on a considerable practical experience, which makes it dangerous reading for the undiscriminating. In places, there are blatant inaccuracies; for instance those familiar with the Barbados sugar industry will be surprised to learn that ". . . . . of recent years the replacement of organic manure by artificials has led to the virtual collapse of the island through disease. . .".

All agriculturists will agree with Sir Albert on the dangers of the wholesale exploitation of tropical soils, and of soil erosion generally. It is also obviously bad practice to try to breed new varieties of crops in order to maintain yields on soils which are deteriorating owing to bad agriculture. It is equally obvious that spectacular results will be obtained by dressing exhausted soils with compost, while most scientists, excepting only those with an extreme and possibly misguided enthusiasm for chemical manures, will agree as to the usefulness of compost as a balanced manure for maintaining soil fertility and for the preservation of a good tilth in the heavier soils. Sir Albert, however, departs from generally accepted ideas in several important directions, without providing any genuine scientific proof of the theories which he has treated as facts. Whilst the great importance of micro-organisms in soil processes is justifiably stressed, the results of certain classical observations on mycorrhizal associations have been generalised, so that for many crops in which the association has been demonstrated it is assumed to be beneficial, although no real proof is forthcoming. It is also suggested that plants can absorb complex organic nitrogenous compounds from the soil; that diseases and pests of crops can be controlled, and the "running out" of varieties prevented, by composting, which is also held to produce "better quality" and to confer resistance to disease on the men or animals which feed on the produce of soils treated in this way. Examples are given of small communities whose health has been improved by eating such produce, but one cannot help wondering to what extent such benefits were purely the result of a more adequate supply of fruits and vegetables resulting from their horticultural pursuits.

The danger of the half truth is apparent in the suggestion that crop diseases can be controlled by the application of compost to the soil. Most plant pathologists will agree that it is possible to divide plant pathogens fairly sharply into two groups; the dangerous primary parasites, which can attack their host plants in almost any circumstances, and the "conditional" parasites which can only do damage when their host plants are growing poorly. Many of the latter group can be controlled by improvements in cultivation methods, such as composting, but the probability is that the former group will be unaffected. The argument that because some diseases can be controlled in this way all can be so controlled is fallacious. For example, neither witches' broom disease of cacao (*Marasmius perniciosus*), nor banana leaf spot (*Mycosphaerella musicola*) can be controlled in this way, both spreading rapidly where climatic conditions are favourable to them. The eelworm, *Hetrodera marioni* and the wilt due to *Sclerotium rolfsii* continue to give trouble in the vegetable garden at the Imperial College of Tropical Agriculture after years of organic manuring, which has completely changed the nature of the original soil.

Had Sir Albert been content to point out, in a semi-popular book of this nature, the proved value of sound agricultural methods, involving the return to the soil, as compost, of valuable plant and animal wastes, the work would have proved most valuable. Unfortunately, he has seen fit to obscure his main theme by unsound generalisations and extravagant claims. The book is written in a somewhat journalistic style with a tendency to tedious repetition (the reader may become rather tired of "the earth's green carpet") but if critically read will provide ample food for thought.

R. E. D. Baker

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THE PREPARATION OF REFINED RICE BRAN

BY

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IN countries where the growing of large areas of rice is an established practice a correspondingly well-developed rice milling industry may exist. In such cases various grades of rice are obtained from the mills and well defined by-products are separated. The offals which can be produced are: hulls, first break bran, second break bran, pearling cone polish and brush polish. According to the type of mill these by-products may appear singly or in different degrees of combination.

On the other hand when rice growing is less extensively practised milling methods are inferior and separation of the offals into different types is either not attempted or inadequately performed. In Trinidad, for example, the customary "rice bran" (subsequently referred to as "mixed rice offals") contains not only the true brans and polishes but also the hulls and the lowest grade (broken or brewers') rice. Even in localities where good milling procedures are normally used low grade rice brans are produced by inferior mills. Such cases have been mentioned by Fraps (1916) for Texas, by Bray (1943) for Louisiana and by Tirol (1932-33) for the Philippines. Butler (1945) commented on the production of combined milling offals in Tanganyika which seem similar to those produced in Trinidad.

The inclusion of the rice hull fraction in the bran fraction is responsible for lowering the feeding value of rice offals. It has long been realized that the nutritive value of rice hulls is very low (Fraps (1919)) and that, owing to their physical nature, the hulls may sometimes produce detrimental effects in the alimentary tract (Stubbs, Dodson and Browne (1904)). The crude fibre content of rice hulls is high and, probably because of the silica content, of low digestibility While some finer particles of hull must inevitably enter the true bran fraction the Association of American Feed Control Officials, to prevent grossly contaminated samples being offered for sale, have adopted the following standard for rice bran: it must contain not less than 11 per cent. of crude protein and 10 per cent. of crude fat and not more than 15 per cent. of crude fibre. Since Fraps (1916) has shewn that true rice bran contains 8 per cent. of crude fibre and that rice hulls contain 39 per cent., it follows that if the degree of contamination seriously exceeds 20 per cent. of hulls in a bran-hull mixture, the crude fibre content will exceed this legal maximum.

Nutritional characteristics of rice offals

Rice bran and rice polish are of particular interest as sources of vitamins of the B complex and of protein. The investigations of Kik (1942) indicate that the proteins of rice bran and rice polish are of reasonably good biological value. His findings, in experiments where the proteins were fed at a 5 per cent. level, were: 84.9 per cent., 82.9 per cent., 81.5 per cent., 72.7 per cent. and 66.6 per cent. for rice bran, rice polish, casein, whole rice and polished rice respectively.

In Table 1 the amounts of certain vitamins of the B complex present in rice offals are given. The data are from Jacobs (1944). Wheat bran is included for purposes of comparison.

Table 1

The concentration of certain B complex vitamins in rice offals and wheat bran. All values expressed as micrograms per gram of dry matter

Material	Aneurin	Ribo-flavin	Niacin
Rice offals:			
Hulls	1.11	0.76	18.6
First break bran ..	27.33	2.68	332.0
Second break bran	17.86	1.77	286.3
Pearling cone polish	22.88	1.62	290.3
Brush polish ..	20.95	1.34	268.0
Wheat bran ..	5.20	3.50	320.0

It appears that rice offals, as a whole, are about four to five times as rich in aneurin as wheat bran but contain only about half to two-thirds as much riboflavin. The niacin contents are closely similar.

The use of rice offals in rations

Since rice offals are good sources of vitamins of the B complex, their place is more logically in the rations of poultry and swine than in ruminant rations. Owing to the synthesis of water soluble vitamins which occurs in the rumen as a result of microorganism activity, it appears that rice milling offals, unless available in excessive amounts and at low cost, would be more suitably absorbed in the rations of non-ruminants as these animals are dependent on external sources for B complex supplies. However, the low tolerance of non-ruminant species for fibre, especially where high production performance is required, makes it of importance that the rice by-products offered should be as free from hulls as possible.

In Table 2 are given rations containing rice offals which have been successfully used for different classes of stock.

Refinement of mixed rice offals

As stated above the locally available mixed rice offals are a mixture of all the milling offals together with a variable amount of broken rice. Attempts to separate the nutritionally valuable fractions from the hull fraction were made, the results of which are given below.

1. *Hand separation*

Seven samples of mixed rice offals were obtained. In this and in the subsequent study, samples were from different mills. As far as possible offals originating from paddy from different sources were obtained in an attempt to explore the range of variation existing.

The fractionations were carried out using a nest of sieves of the type used in mechanical analysis of soils. The results are given in Tables 3.

Table 3

Fractionation of mixed rice offals by hand sifting. Values given in percentages

No. of Sample	Residue on 30 mesh screen	Passed 30 mesh screen	Passed 40 mesh screen	Passed 60 mesh screen
1 ..	69	31	16	6
2* ..	69	31	12	2
3 ..	58	42	17	4
4 ..	69	31	14	6
5 ..	70	30	12	3
6* ..	68	32	14	2
7 ..	67	33	12	3
Mean ..	67	33	14	4

* Parboiled samples.

Examination, using the eosin test described below, of the different types of material produced by this method of fractionation indicated that the residue on the 30 mesh screen consisted almost entirely of hulls and broken rice. The materials passing the different screens contained fine hull fragments, rice bran and finely broken rice. Because of differences in particle size most of the hull fragments were removed by the 30 and 40 mesh screens while the finer broken rice and bran fragments passed through.

2. *Mechanical separation*

In view of the findings in the hand separation study mechanical separation was next attempted using a wire mesh screen.

The grading machine used consisted of a power-driven axle bearing three square wooden bars fixed co-axially. On rotating the axle those bars pass in succession over a hemicylindrical screen made of 40 mesh to the inch B.S.W. gauge No. 38 wire. The screen and the rotating axle with the attached bars are at the bottom of a hopper which is charged with mixed rice offals. The refined rice bran is the material passing the screen.

The only source of power available was a 12 brake horse power vertical Petter diesel engine. This was unnecessarily powerful since the grader could probably be driven by a 2 horse power engine.

After removal of the refined rice bran the hull-broken rice mixture remaining in the hopper was hand-winnowed and the broken rice separated. The results, together with the costings, are given in Table 4 for five fractionations.

Quality of refined rice bran

1. *Chemical composition*

The chemical composition of some of the rice brans obtained from the machine grader during the year it has been in operation is given in Table 5.

2. *Hull contamination*

From the analytical data in Table 5 the degree of contamination of the refined rice bran with rice hulls can be calculated. Fraps (1916) derived the formula :

$$X = \frac{F-8}{31} \times 100$$

where X = the percentage of hull contamination and F = the percentage of fibre in the offals. The refined rice bran prepared in the present study thus contained about 20 per cent. of hulls.

Table 4

Fractionation of mixed rice offals by machine grader and hand-winnowing together with costings

Sample No.	Yield per 100 lb. of mixed rice offals			Cost, in cents of,			
	Refined rice bran	Broken rice	Hulls	100 lb. mixed rice offals	Operation of grader*	Hand winnowing	Total cost
	lb.	lb.	lb.				
1	32	13	55	34	32	6	72
2	28	10	62	30	30	5	65
3	33	8	59	32	38	3	73
4	32	9	59	37	32	4	73
5	27	11	62	33	27	5	65
Mean	30	10	60	33	32	5	70

* This charge includes depreciation, operating costs and labour charge for engine and grader.

Table 2

The use of rice byproducts in livestock rations. All values expressed as percentages

Feedingstuff	Horse-kind		Dairy Cattle		Beef cattle				Swine				Poultry					
Refined rice bran																	20	20
Rice bran ...		25	20	29.5		73	37.5	75		43	51		20	10	20			
Rice polish ...	25		20	19	77		37.5		45.5			51	20	10		20		
Brewers' rice ...				19									20					
Alfalfa meal ...													10	5	5	5		
Barley, ground ...	25								45.5	45								
Cod liver oil ...													2				0.5	
Cornmeal	42										41	41	8	50	50	50	50	52
Cottonseed meal ...		8	40	29	23	27	25	25										
Dried milk ...																	5	
Fish meal ...													5				12	12
Ground limestone				2									4				1.5	2
Linseed oil meal ...	8																	
Meat scrap ...													10	10	10	10		
Mineral mixture*														5	5	5		
Oats		25	20											10	10	10		
Salt				1.5														
Sorghum grain ...		42																
Soyabean meal ...																	10	13
Tankage									9	12	8	8						
Reference ...	A	A	A	B	A	A	C	C	A	A	D	D	A	E	E	E	F	G

*30 per cent. Bonemeal, 60 per cent. ground oyster shell, 10 per cent. salt.

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Table 5

Composition of refined rice bran. In percentages

Sample No.	Moisture	Crude protein	Ether extract	N-free extract	Crude fibre	Ash	Ca.	P.
1 ...	12.6	10.1	4.4	48.2	12.5	12.2	—	—
2 ...	10.8	9.4	9.5	39.1	17.3	13.9	0.05	1.14
3 ...	10.6	10.0	9.1	45.9	14.4	10.0	0.11	0.85
4 ...	12.0	8.5	8.1	39.6	17.2	14.6	0.10	0.86
5 ...	12.6	9.1	8.4	39.6	15.0	15.3	0.07	0.92
6 ..	11.6	9.6	7.5	45.7	13.7	11.9	0.12	0.94
7 ...	11.6	9.4	7.2	49.9	11.0	10.9	0.08	0.88
Mean ..	11.7	9.4	7.7	44.1	14,4	12.7	0.09	0.93

Considerable difficulty was experienced during the early stages of this study owing to the lack of a method for determining rapidly the degree of hull contamination of the products separated. Although chemical analysis was required in some cases a more rough approximation was adequate in others. To this end a staining test was devised which served the purpose. Different operators agreed, among themselves, in grading offals by this test.

The test is carried out as follows: a small representative sample of the offals is placed on a white glazed tile and a few drops of a one per cent. aqueous solution of eosin are added. No more eosin is used than is necessary thoroughly to moisten the sample. After a few seconds a small amount of water is added sufficient in amount to disperse the bran in a thin layer. On examination with a hand lens the rice bran and broken rice fragments appear stained a deep pink, while hull fragments are orange coloured.

The test would presumably be satisfactory for detecting intentional adulteration of commercial rice brans with finely ground hulls.

Discussion

The method described of fractionating mixed rice offals yielded a material which was slightly below the American standard for crude protein and crude fat content. In crude fibre content the refined rice bran was, on the average, close to the legal limit for American rice brans. These results indicate that a separation method such as was used in the present study is suitable for recovering the nutritionally valuable fractions of mixed rice offals.

If the cost of preparation be divided proportionately between the refined rice bran and the broken rice the cost per pound of these products is 1.75 cents. This compares favourably with the prevailing cost of 4.75 cents per pound for wheat bran and 5.2 cents per pound, wholesale, for second grade milled rice. Further studies are being undertaken on larger scale production of refined rice bran.

The use of refined rice bran to replace imported wheat bran and oats in the starting and rearing rations of poultry will be reported later. It appears to be a satisfactory substitute.

Summary

The preparation of refined rice bran from mixed rice milling offals was described.

The product was similar to ordinary commercial bran obtained from better class rice mills.

A study of costings was included.

Acknowledgment

The authors are indebted to Mr. E. H. Achong for assistance at all stages of this investigation.

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EFFECT OF DEPTH AND FLUCTUATIONS OF WATER-TABLE ON THE GROWTH OF SUGAR-CANE

BY

F. HARDY

THE results of an instructive and highly suggestive series of experiments, carried out in Jamaica under the direction of Mr. R. V. Holme, Senior Research Officer of the Agronomy Section of the Sugar Manufacturers' Association, have recently been published in the Quarterly Journal of the Association, **7**, 2, 1943, 7-11, and **9**, 1, 1945, 8-9, under the title "Box Experiment". The investigation may be divided into two parts which mainly concern the effects of (A) fluctuating water-table and (B) constant level water-table, on the growth and yield of sugar-cane. The methods and results may conveniently be considered under these two headings.

(A) Fluctuating water-table

The investigation in which the effects of water-table fluctuations were tested was begun in May, 1943, at Grey's Inn Estate. The primary object was to examine the effects of three different heights of water-table on three different varieties of sugar-cane, but it so happened that the arrangement made for maintaining a steady level of water in the various cultures failed to attain its object; indeed it actually caused a marked fluctuation in water-table level so that the results obtained may serve to assess the effects of rising and falling water in the soil.

Thirty six (36) open-ended wooden boxes were constructed, each 2×2 feet in sectional area; 12 were made 1½ feet tall, 12 were made 2½ feet, and 12 were made 3½ feet tall. They were all filled with topsoil and set out in random fashion in a dam or trench containing water six inches deep, supplied from "unfailing springs". The boxes were planted with cane-setts of the varieties B.34104, B.3439 and POJ.2878. There were thus four replicates of each culture having a particular depth of water level and containing a particular cane variety. During a long summer drought, the level of the water in the trench fell nearly six inches, and during the wet season it rose six inches above mean level.

Results:

The most outstanding difference between the cultures was the wide variation in the number of tillers formed. For varieties B.3439 and POJ.2878, quickest sprouting occurred in the shallowest box but tillering practically ceased between the 5th and the 10th weeks for this treatment. In the deeper boxes, the number of shoots formed increased continuously to the 10th week. At the end of this period, the water-level fell and tillering was consequently increased in the shallowest box but retarded in the deepest; the effect was not marked in the box having intermediate depth. For the variety B.34104, growth and development were much more regular and the effect of the drought period was not marked. Each of the deeper ("dry") cultures tillered more profusely than the shallowest (or "wettest") culture, though all cultures ceased tillering at the 13th week. It was concluded from these observations that the variety B.34104 "possesses a more flexible rooting habit" than the two other varieties, since drought exerted least effect on it.

With regard to stem elongation, systematic measurements showed that, for each variety and for each depth of box, the first-formed shoots grew fastest during the first six months, and the last-formed grew slowest or not at all. It was also noted that stem elongation was very uniform for each variety and each depth of box; the effects of drought and rain were imperceptible. At the end of October when the arrowing stage was approached, the rate of growth diminished in all the shoots. Furthermore, average lengths of the strongest shoots varied little in the different varieties and for the different depths of box. It was concluded from these observations that drainage may play an important part in modifying the stooling (or tillering) capacity of any sugar-cane variety. The optimum depth of drained soil for satisfactory stool formation was thought to be 2½ feet, but for best results, good drainage to this depth must prevail from the very beginning of the plants' growth, since tillering takes place mostly during the first three months after planting.

Regarding the yields of cane given by the different cultures, it is stated (though no actual weights were recorded) that lowest returns were obtained from the shallowest box-cultures in which the mean water-level was highest. It should be noted that the fluctuations of water-table, which at one period reduced the depth of the rooting-zone to 6 inches and at another increased it to 1½ feet, exerted the most deleterious effects in the shallowest box.

(B) Constant water-table

This investigation was carried at Worthy Park Estate. As before, 36 wooden boxes of the same three sizes as before were filled with topsoil. They were placed on a level clay surface covered with a thin layer of porous soil. Water was maintained over this surface at a constant level by means of an inflow pipe provided with a ball-cock valve and an overflow. The boxes were planted with cane setts, variety not stated but presumably the same for all the cultures. Besides the three depths of water-table, two different amounts of ammonium sulphate (namely, one and 6 cwt. ac.) were applied, either in one

dose or in two, and either 4 weeks before planting, at the time of planting, or 4 weeks after planting. The different treatments were equally divided between the 36 boxes.

Results

The actual yield-data are tabulated below :—

			Mean yields (wt. per stool)
1.	Different heights above water-table	1 foot	53.6 lb
		2 feet	48.5 ,,
		3 feet	50.1 ,,
2.	Quantity of sulphate of ammonia per acre	1 cwt.	51.0 lb.
		6 cwt.	50.4 ,,
3.	Different planting dates :		
	before planting,	—4 weeks	49.6 lb.
	at planting,	0 weeks	56.3 ,,
	after planting,	+4 weeks	46.3 ,,
4.	Number of applications of S/A.	1 appli.	52.6 lb.
		2 appli.	48.9 ,,

When tested by the analysis of variance, none of the treatments had apparently exerted any appreciable effect on the yield of cane, except that artificial manure applied at planting time gave a significantly greater yield than manure applied four weeks after planting, the differences being 10 lb. weight. The requirement of nitrogen of this soil was negligible, so that neither the total amount of manure supplied nor the number of applications affected the yield appreciably.

It is particularly important to note in this experiment that *the yield for the shallowest box was not significantly different from that of the two deeper boxes.* The comparative rooting volumes for the different-depth cultures were 4, 8 and 12 cubic feet respectively, yet the root systems of the sugar-canes seem to have been capable of adjusting themselves to these various volumes and to have procured all the nutrients the plants required for satisfactory growth. It must be remembered, though, that the soil was particularly rich in plant nutrients, having a plentiful supply of available nitrogen and presumably of other nutrients as well. Whether or not similar successful root adjustments would be made in different depths of a soil particularly poor or deficient in nutrients has apparently not yet been investigated.

Conclusions :

The growth of the root system of plants, or at least those parts of it that are involved in the absorption of water and nutrients in contradistinction to those having purely mechanical functions, is decided by various responses or "tropisms", notably, hydrotropism and chemotropism; that is, absorbing roots tend to grow in the direction of increasing water and nutrient concentrations. Active root systems also require adequate soil aeration for successful functioning, since energy derived from respiration is needed for absorption. Thus, provided the soil is richly supplied with nutrients and its water-supply is maintained at a suitable value concomitant with adequate aeration, then there is no reason why the root-system of plants should not develop satisfactorily in quite a shallow rooting zone. Indeed, many plants in nature grow and thrive satisfactorily in shallow soil containing an abundant supply of nutrients derived from decaying litter and crumb soil which comprise the uppermost layers. Soils whose surface layers are rich and continuously moist, so long as water-table fluctuations do not cause periodic asphyxiation of newly-formed active roots, may thus present a suitable and entirely satisfactory medium for the growth of certain plants, particularly grasses, so that, in these circumstances there should be no particular need for deep cultivation as a means of extending the rooting zone downwards. Thus the growing of sugar-cane in narrow banks, one to 1½ feet high, such as is practised in the Louisiana system (as the account of the above "box" experiments stresses), has proved to be highly satisfactory in certain sugar-growing areas, provided water has not been permitted to accumulate in the furrows in wet weather so as to cause periodic fluctuations in water-table level. Similar suitable conditions may also obtain in the cambered-bed system of cane planting where the drains between beds are sufficiently deep.

THE AFRICAN OIL PALM

In this paper the detailed information on the African oil palm, *Elaeis guineensis*, compiled by the author, is presented under the following heads: Product and its source; use and importance; history and distribution of plant, wild and cultivated; horticulture (as practised in different parts of the world); harvesting and processing; the oil palm in America. The last chapter makes it clear that the industry has great possibilities in Brazil, particularly in Bahia and other coastal States and in certain fertile regions of the interior once the problems of transport, modern machinery and labour have been solved. Two types are grown in Brazilian plantations: the "sombra" variety, producing a medium-sized fruit, and the "caboclo" variety, which produces an enormous fruit cluster with individual fruits as large as a small apple. Under conditions of shade, in marshy places, swamps and wet clay soils the African oil palm should be supplemented by the corozo palm (*Alfonsia oleifera* or *Corozo oleifera*), which is grown in Central America, Colombia and the Amazon region. The significance of additional oil-producing palms occurring in the wild form from Mexico to southern Brazil has not been fully realized yet. In Brazil, the potential value of the wild babassu palm nut (*Orbignya barbosiana*) crop alone is estimated to be 5 times that of the coffee crop.—(Abstr. 1292 in *Hort. Abstr.*, **15**, from *Lloydia* 1944, **7**: 101-20.)

SOIL MICROBIOLOGY AS A FIELD OF SCIENCE *

BY

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The question is frequently raised concerning the position occupied by soil microbiology in the field of knowledge, especially its relation to other biological sciences, on the one hand, and to agricultural sciences, notably soil science and crop science, on the other. In order to elaborate upon this relatively new branch of science, which is frequently only vaguely understood and often little appreciated, it is sufficient to define first the student of the subject, namely, the soil microbiologist.

The soil microbiologist

A soil microbiologist, as the name implies, is a microbiologist who is concerned with soil microorganisms. His objective is to determine the nature of the microorganisms inhabiting the soil. He is concerned with the activities of these organisms and their characteristics of growth. He analyzes the interrelationships of the various elements of the microbial population of the soil, the reactions with which they are concerned, the influence of soil conditions on the microorganisms comprising the soil population, and the effects of the activities of the population on the soil and on the plants which develop in it. Finally he seeks means of bringing the resources of the soil population to the service of man.

In common with other microbiologists, the soil microbiologist is a biologist whose major interests centre about the microscopic forms of life. He is also a biochemist, since he is concerned with the chemical reactions brought about by these microscopic living systems. He is interested in problems involving inorganic and physical chemistry: their importance is evident in the various reactions between inorganic compounds produced by microorganisms and soil materials, and the function of inorganic materials in the development of the microorganisms. He deals with soil structure, which is greatly affected by microbial development, and this as well as other effects of the soil microorganisms involves some consideration of physical chemistry. He deals with a special medium, the soil, in which these organisms live, not in pure culture but in the form of highly complex populations; these comprise many thousands of species, which exert upon one another a variety of associative and antagonistic effects. Because of these complex problems, the cooperative efforts of groups of workers bringing their special training to bear upon such problems is often required.

The soil microbiologist has, therefore, certain functions to perform which distinguish him, on the one hand, from other microbiologists and, on the other hand, from other soil investigators. His principal interest is often only in one of the fields listed below, but he has also a certain perspective recognition of the work of his fellows in other branches of the science, as well as in the related sciences of microbiology, plant physiology and biochemistry. The major fields of interests of a soil microbiologist may be briefly listed under the following categories:

(1) The microbiological population of the soil, including the bacteria, fungi, actinomycetes, protozoa, algae and other lower forms of plant and animal life: the soil microbiologist develops methods for the isolation and for the determination of the abundance and distribution of the various members of this population. These methods are quite distinct from corresponding methods employed by other microbiologists who study animal or plant diseases or those who are concerned with fermentations. Some of the microorganisms found in the soil are characteristic of this particular natural substrate, and occur very seldom, if at all, in other natural media. This is true of certain bacteria, such as the *Azotobacter* group and the nitrifying bacteria. These organisms may be found in other substrates, such as water basins and on dead plant and vegetable matter; they find in the soil a natural habitat. The relative abundance and the distribution of these organisms in the soil depend upon the nature of the soil, its treatment, the crop grown and a variety of other factors. Various groups of fungi, including some mucors and species of *Rhizopus Trichoderma*, and *Penicillium*, may be found in a variety of substrates, such as spoiled food or mildewed cloth, but it is in the soil that these species find their natural habitat and from which they are distributed by wind and water. The specific nature of these and of many other fungi, as well as their relative abundance in a soil depend entirely on the nature of the soil, its treatment and various environmental factors. Certain Basidiomycetes and Myxomycetes, for example, are characteristic of forest soils and of other soils rich in plant residues. The actinomycetes are represented in the soil by certain groups which are characteristic of the soil and are found only to a very limited extent in other substrates. The genus *Streptomyces*, for example, which comprises those forms that produce a well-developed aerial mycelium, is represented in the soil by hundreds of species, whereas the genus *Micromonospora* occurs largely in high temperature composts and in lake bottoms. Many other groups of microorganisms are found largely in the soil and only seldom elsewhere. The fact may thus be emphasized that the soil possesses a marked and characteristic microbiological population. Special

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methods are developed for the study of this population. Media are selected with a view to allowing the development of the greatest number of organisms in a limited space. Extensive use is made of enrichment methods and of selective culture methods, all of which have become essential tools in the hands of the soil microbiologist.

(2) The numerous interrelationships of the soil population, as well as the relations of these organisms to higher plants: these involve variety of reactions, such as the struggle for development, the competition for nutrients, the favourable and unfavourable effects of one upon the other and the importance of these effects in determining the dominant populations of soil as compared with that of other natural environments. These phenomena also involve the part played by saprophytic soil microorganisms in the elimination of plant parasitic microorganisms. It involves the broad aspects of associative and antagonistic effects of microorganisms, the elucidation of which contributed materially to the development of our knowledge of the production of antibiotic substances. The relationships of microorganisms to higher plants comprise activities which are either adverse or favourable to plant growth; the latter comprise symbiosis of microorganisms with legumes and mycorrhiza formations. The complexity of the reactions taking place in the soil and the difficulty of obtaining a true perspective of the many processes involved from simplified studies carried out under artificial conditions in the laboratory become self-evident.

(3) The decomposition of plant and animal residues on the surface of the soil as in composts, as well as in the soil itself and the formation of humus: when plants and animals die, or when the residues of their metabolic processes, either in the form of excreta or as dead tissues, find their way into the soil they become subject to attack by large numbers of microorganisms. The nature of these organisms and their relative abundance will depend largely upon the chemical composition of the materials undergoing decomposition, upon the rate of decomposition of the various specific chemical constituents of these materials and upon the environmental conditions, such as reaction of soil, moisture content, aeration and temperature. Among the chemical constituents, the most important are the simple carbohydrates, the starches, pectins and hemicelluloses, the true cellulose and lignin, the proteins and other nitrogenous compounds, the mineral elements, notably the phosphates, sulphates and various bases and their organic and inorganic forms. Some of these constituents, such as the simple carbohydrates and some of the proteins, are attacked very readily and by a great variety of organisms; large numbers of organisms are capable of decomposing cellulose, some of these organisms preferring this carbohydrate to other sources of carbon; some plant constituents, such as lignins and waxes, are attacked only slowly and by a few types of organisms. The rate of decomposition of the carbohydrates may depend to a large degree upon the presence and relative abundance of nitrogenous compounds. The fats, waxes, lignins and certain other compounds may gradually accumulate, because of their relative resistance to decomposition as compared to the other plant and animal constituents. Side by side with the decomposition processes the microorganisms synthesize considerable cell substance, the amount of synthesis being in many cases as much as 30 to 50 per cent. of the material destroyed. The resistant constituents of the plant residues together with the synthesized cell material gradually give rise to the organic matter of the soil commonly known as humus. This material is not of a homogeneous chemical nature, but it possesses certain properties which distinguish it clearly from other forms of organic matter. Its nature depends upon the composition of the material from which it has originated, the extent of its decomposition and the nature of the synthesized microbial cell substances. Although humus is fairly resistant to decomposition, it is subject to slow and gradual attack by a variety of microorganisms. This can be measured by the continuous stream of carbon dioxide given off during the decomposition process and by the liberation of the nitrogen as ammonia.

(4) The liberation, through the activities of microorganisms, of the nutrient elements essential for plant life in available forms; namely, the carbon as carbon dioxide, the nitrogen as ammonia, the phosphorus as phosphate, the sulfur as sulfate, and others: without these microbial activities, the limited supplies of these elements on the surface of the earth would soon become locked up in the form of plant and animal life, thus bringing to a standstill the development of new life. The varied activities of the soil-inhabiting microorganisms keep these elements in continuous circulation. These processes take place in a series of reactions many of which are brought about by different organisms with different physiological mechanisms. In studying these reactions the soil microbiologist thus contributes to a knowledge not only of soil processes but of microbial physiology as a whole. Let us take the cycle of nitrogen as an illustration. The transformation of the nitrogen in the protein to the amino acid stage, and later to the ammonia stage; the assimilation of the ammonia to build up microbial proteins; the oxidation of the ammonia to nitrate; the reduction of the latter to nitrite and to atmospheric nitrogen—all these involve a series of biochemical mechanisms, the elucidation of which has contributed materially to microbial physiology as a whole.

(5) Nitrogen-fixation bacteria and the mechanism of the fixation process: no other group of microorganisms and no other microbiological process are so characteristic of the soil as the reactions involving the fixation of gaseous nitrogen and its transformation into complex organic compounds. Although some of the

bacteria capable of fixing nitrogen are found in other natural substrates, such as water basins, and some nitrogen may be fixed under these conditions, it is the soil which may be looked upon as the natural habitat of these organisms. The process of nitrogen-fixation contributes largely to the fertility of the soil and toward making it a medium favourable for extensive plant growth. Whether the leguminous plants harbouring the root-nodule bacteria are growing in a wild state, whether they are cultivated in the form of special crops, or whether they are used in a given crop rotation for soil improvement purposes, the continuous, even if slow, increase in the supply of soil nitrogen resulting from the growth of such crops has long been recognized and advantage taken of it in developing systems of husbandry. The knowledge gained from the study of the mechanisms of the fixation process, although not fully elucidated as yet, has greatly contributed to the understanding of one of the most significant biological reactions and of the physiology of a unique group of microorganisms.

(6) The process of nitrification: the soil microbiologist has largely initiated and has been chiefly responsible for the development of the knowledge gained on the autotrophic bacteria as a whole and the nitrifying forms in particular. Volumes have been written on the subject of nitrification, one of the most important processes in the soil and one of the most fascinating chapters in microbiology. The knowledge of the very peculiar physiologic characteristics of a group of bacteria, capable of utilizing the energy obtained by the oxidation of the ammonia to nitrite and of the latter to nitrate, has greatly enriched microbial physiology. These organisms may be present in other substrates, such as water basins and activated sewage disposal systems, but it is the soil that forms their natural habitat. Whether they have found their way from the soil into lakes and seas, and there is ample evidence for this, or whether they were first living in water basins before becoming established in the soil is a purely philosophical question. At present, they are universally present in soil, whereas in the sea they are largely found in areas close to land. There are but few cases on record of soils lacking in nitrifying bacteria. This may be due to excessive acidity or to anaerobic conditions, which either prevent the growth of these bacteria or inhibit the process of nitrate formation. The rate of accumulation of nitrate in the soil was found to correspond to the extent of microbiological activities in the soil as a whole and incidentally to soil fertility.

(7) Various other processes of oxidation and reduction brought about by soil microorganisms. Such processes may become, under certain special conditions, of great theoretical significance and practical importance. These include such reactions as the oxidation of sulfur to sulfuric acid and the oxidation of a variety of other inorganic and organic compounds; among the reduction processes, it is sufficient to mention the reduction of sulfate to hydrogen sulfide, of nitrate to nitrite, to ammonia or even to atmospheric nitrogen, and of various complex organic compounds. The organisms responsible for these processes may develop only when a combination of certain factors are favourable. Sulfate-reducing bacteria develop, for example, when conditions are anaerobic, when sulphate is present and when organic matter is provided. These reactions may either be important in themselves, as in the loss of nitrogen, or they may be responsible for secondary reactions, such as the corrosion of metals accompanying sulphate reduction.

(8) The rôle of microorganisms in the conservation of the soil: this important function has become recognised only recently. Through the cell material that is synthesized, especially the mycelial structures of fungi, and through the various products of cell metabolism, such as the slimy products of bacteria, microorganisms exert various physical and chemical effects upon the finer soil particles. This results in the aggregation of the particles and consequently in their rapid removal from the soil by flowing waters or strong winds. It is becoming more and more evident that one of the major problems in soil conservation is to supply a sufficient amount of organic matter and other nutrients to the microorganisms of the soil. These agents, through their processes of decomposition and synthesis, take a highly active part in binding the soil, thus preventing the breakdown of the soil structure through atmospheric agencies.

The soil microbiologist is thus found to deal with a highly complicated group of problems, which are primarily biological in nature but which have many chemical and physical phases and applications. Soil microbiology, like the older science of botany, has its ecological aspects, its physiological and biochemical problems and numerous practical applications. The applications bear, first of all, upon soil fertility and crop production. By reason of the diversity of the reactions which take place in the soil, it is necessary for the soil microbiologist to study and understand the physiology of various microorganisms. This is largely the reason why he has particular interest in and has made so many contributions to the field of microbial physiology.

There are also other phases and branches of microbiology to which the soil microbiologist has made important contributions. His field is thus not limited to the study of a few processes by simple methods, and the importance of soil microbiology is not restricted to a knowledge of practical crop production. With this in view, it becomes essential to recognise the relation of this science not only to other major sciences, but especially to those newer or special sciences with which it has had the greatest contact.

Soil microbiology and other sciences

The soil microbiologist is thus shown to be in a position to make important contributions not only to the knowledge of the soil, plant nutrition, crop

production or agronomy, and forestry, but also to several apparently distinct sciences. It is sufficient to mention, in this connection, the sciences of aerobiology, the biology and chemistry of fresh and salt-water basins, the broad field of ecology and plant pathology, the problems of food preservation, of sanitation and of sewage purification, as well as the domain of public health and medicine. Brief outlines of some of these relations will suffice.

Most of the fungi and bacteria that one finds in the air, no matter how far away from the land surface, have originated from the soil that has been carried by the wind in the form of dust particles. These organisms, having had their origin in the soil, behave in all respects like typical members of the soil population. This phenomenon not only has a bearing upon the problem of allergy but also upon a certain type of deep-seated infection that is often traced to certain soil-inhabiting microorganisms.

Any survey of the microbiological population of water basins, whether small land-locked or large oceans, will reveal certain facts that have an important bearing upon the close relationships between the nature of such populations and that commonly found in or characteristic of the soil. Bacteria, for example, are found in much greater abundance in those areas of the sea that are close to shore than in regions distant from land. The occasional presence in sea water close to shore of such typical soil organisms as specific fungi, actinomycetes and various bacteria, which are absent from or occur only rarely in waters far away from land, point to their soil origin. Certain special groups of bacteria, such as the nitrifying and aerobic nitrogen-fixing forms, that are found to occur with great regularity in waters close to land and are absent elsewhere in the sea, led to the question whether these organisms occur there only because they have been washed in from land or whether they are true sea-inhabiting organisms.

The science of ecology owes a great deal to our knowledge of soil-inhabiting microorganisms. One need only mention the effect of root-nodule bacteria on the growth of legumes, which influences, in turn, the growth of grasses and other plants; the effects of mycorrhiza fungi and certain other soil-inhabiting organisms upon forest vegetation and forest succession is another illustration.

Various investigators and technologists concerned with problems that are apparently totally unrelated to soil microbiological processes have come to the soil for an answer to their specific needs. Out of a number of illustrations that may be cited, it is sufficient to draw attention to the following three that recently have aroused great interest: (*a*) the subject of spoilage and deterioration of textiles, of leather goods, of wooden structures and of many other types of service materials, under conditions of high humidity and high temperature; (*b*) the search for microorganisms producing antibiotic substances; (*c*) the search for organisms concerned in various industrial fermentations.

The problem of "mildewing" of cotton cloth, of woollen material and of leather goods has recently received renewed emphasis because of the huge quantities of such material that are being handled under moist and humid conditions. The various procedures used for preventing rapid deterioration of these materials brought out the fact that the fungi and bacteria that are responsible for the attack are largely of soil origin. The test organisms used in evaluating the resistance of such materials to "mildew" and to "rot" are typical soil forms. When a very severe type of test procedure is to be used, a soil suspension containing a number of different organisms is employed for inoculation purposes, or the material is actually buried in the soil for a given time under favourable conditions of moisture and temperature. These are not direct problems for the soil microbiologist, but much can be gained from a knowledge of the microbiological population of the soil and of the physiology of its constituent forms. This is true especially of the resistance of these organisms to poisons, their nutrient requirements, especially their ability to attack cellulose, the effects of relative humidity, etc.

The student of antibiotics and of their application to chemotheraphy has recognised the fact that some of the most important organisms that produce antibacterial substances find their permanent or temporary habitats in the soil. Thus, *Bacillus brevis* that produces tyrothricin is a typical soil bacterium; *Penicillium notatum* and *P. chrysogenum* that form penicillin are soil fungi; *Streptomyces lavendulae* and *S. griseus*, that give rise, under special conditions of culture, to streptothricin and streptomycin are soil actinomycetes. Investigators in numerous laboratories throughout the country are at this very moment enriching the soil with all sorts of pathogenic bacteria and other microorganisms, in order to stimulate the development of antagonistic forms that could be utilized for the production of desirable antibiotic substances. Literally thousands of fungi, bacteria and actinomycetes are now being isolated from soils or from composts, and tested for the production of such antibiotic agents. Here as well, a knowledge of the composition of the complex microbiological population of the soil and its variation under the influence of treatment would have saved a great waste of time and energy. Stories are told of aeroplanes collecting soil samples from all over the world, and of automobile trips throughout North America gathering bits of soil from which to isolate bacteria or fungi capable of producing specific antibiotic agents.

The contributions of the soil microbiologist to public health and to medicine has thus recently gained added significance. Knowledge already established by the soil microbiologist includes the disappearance in the soil of most of the pathogenic bacteria causing infections and epidemics in man and in animals, as contrasted to the survival of a few important bacterial pathogens, such as those containing tetanus and gas gangrene and of a number of bacteria and fungi causing plant diseases. The relationship of the soil to a variety of other

diseases, such as hookworm and deep-seated actinomycetic infections, is likewise a matter of great importance. Some of these problems require further elucidation.

One could cite other illustrations of contributions of soil microbiology to human welfare, perhaps not so spectacular as the above, but important nevertheless. The dependence of various industrial fermentations upon soil-inhabiting microorganisms is well known. Others include the anaerobic bacteria producing butyl alcohol and acetone, the butylene glycol organisms of both the aerobic and anaerobic types, and many other organisms that produce various organic acids and alcohols. The citric-, fumaric-, gluconic- and itaconic-acid-producing fungi are also largely soil-inhabiting organisms; the very name of the fungus producing the last acid has the flavour of the soil (*Aspergillus terreus*). The industrialist interested in fungi and bacteria producing pectolytic enzymes, as well as proteolytic and amylolytic enzymes, usually goes to the soil in search for appropriate organisms. Some of the vitamin-producing microorganisms are of soil origin.

Although in all the above cases, the soil and its extensive microbiological population were given but little consideration, much benefit could frequently have been derived from a knowledge of the environment in which these organisms live and of their mode of life in the soil.

On the basis of the above facts one may feel justified in postulating the type of training a prospective worker in soil microbiology should acquire. Soil microbiology as well as its mother science, microbiology, is dependent on general bacteriology and on mycology, as well as on physiology and biochemistry. Soil microbiology does not comprise merely the study of legumes and their utilization, of *Azotobacter* and its physiology, or of the cycle of nitrogen in the soil, as glorified by the time-honoured terms of "ammonification," "nitrification" and "denitrification"; it does not comprise merely the enumeration of bacteria and fungi in the soil, or the isolation and identification of so many hundreds of species of these organisms—it is all that and much more. Soil microbiology, like microbiology or bacteriology has a much broader concept and has acquired many ramifications. These comprise specific aspects of ecology, taxonomy, physiology, biochemistry and practical utilisation. The soil microbiologist carries a certain taxonomic responsibility, since it is highly essential to know the exact nature of the organisms involved in a given reaction or group of reactions, and not merely to list these organisms as bacteria, moulds or protozoa. The student who devotes himself to soil microbiology is, therefore, entitled to learn the various phases of this relatively new science.

Summary

It can now be definitely recognised that the soil microbiologist is in a position to make important contributions not only to our knowledge of soil processes and plant growth, but also to microbiology, especially microbial physiology, and to the utilization of microorganisms for various industrial, public health and other processes. The soil microbiologist is able to contribute in many ways to man's capacity to survive, by learning to control the activities of injurious microorganisms and by favouring the processes brought about by the beneficial organisms.

The reason why the broader concept "microbiology" rather than the narrower term "bacteriology" has been used throughout this discussion is that the soil microbiologist has often to pay as much attention to the fungi as to the bacteria, and occasionally also to the protozoa, the algae and even the nematodes and other worms, inhabiting the soil in large numbers. Only a recognition of all these lower forms of life and their many interrelationships can help to elucidate this complex and important science.

MISCELLANEOUS NOTES

Leguminous Shade Trees and Soil Nitrogen

The analysis of 48 soil samples taken at the Tea Research Station, S. India, in the neighbourhood of and at a distance from dadap shade trees indicates that this leguminous tree brings about an increase in soil nitrogen of about 8 per cent.—(Abstr. 1247 in *Hort. Abstr.*, **15,** from *Plant Chron.* 1945, **40** : 135)

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Green Manuring of Replanted Coffee

Observations are being made, on a 2.13 acre site of replanted coffee in South Coorg, on the effect of intercropping with *Crotalaria anagyroides* upon organic matter content of the soil. About 9 tons of green material per acre were ploughed in during the first year from planting, but so far analyses of treated and untreated soils have not shown any appreciable differences. The investigation is being continued. The impression was gained that the coffee comes better through the dry season in association with *Crotalaria* than without it.—(Abstr. 1250 in *Hort. Abstr.* **15,** from *Plant. Chron.* 1945, **40** : 152)

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New Shade Tree for Cacao

It has been suggested by the Rio de Janeiro Botanical Garden that the tree *Erythrina velutina* should be replaced by *Clitoria racemosa* for shading cacao. The latter, an ornamental leguminous tree, unites the advantage of an unusually quick growth and a wide-spreading crown with potential value as a source of edible oil. *Clitoria* comes into bearing after 5 to 6 years, yielding about 22 lb. of seed with an oil content of 22 per cent. and 8 per cent. protein. (Abstr. 1257 in *Hort. Abstr.* from *Agric. Amer.*, 1945, **5,** 117.)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

The Maintenance of Soil Tilth

Good tilth cannot be judged by the feel of a soil when its moisture content happens to be "just right", for in this range, all soils appear to be in good tilth. In the second place, "a fine seedbed in good tilth" is not merely a soil having no large hard clods. It would be possible to smash up the large hard clods of a puddled soil and achieve anything but a good tilth, for the small clods would "run together" after the first rains. Again, it is certain that ploughing and harrowing are not always necessary for the production of good tilth as is shown by the excellent cane crops which were formerly produced from unstumped land using hand hoes. Indeed this leads us to the idea that good tilth is indeed just that condition which exists so notably in newly-cleared land. It is also true that virgin land is rich in plant-foods and this contributes very much to the success of the first few crops taken from such lands. Nevertheless, soil tilth is extremely important and, year by year as the soil is worked with tillage implements, it can readily be seen to lose the friable, easy-working condition it originally had, and to form large clods which tend to produce muddy water from rain or irrigation. It is indeed a fact that a continuous cover of vegetation, both living trees and other plants and dead plant residues, makes the best condition for keeping the soil in good condition and once man disturbs this natural state by using the land in his own way, he sets himself a problem which becomes particularly difficult where rainfall is intense or where irrigation is used.

The technique of farming, under tropical conditions in particular, needs special consideration and the investigations now being conducted in other parts of the world into the system of so called "stubble mulching" will be watched with interest. This system of cultivation aims at merely stirring the soil with shallow working instruments which do not turn under all the vegetative litter but leave a considerable portion on the surface of the soil as a protection against erosion. The plough, which turns over each furrow slice, is an invention of the temperate climates and, although it provides for rapid preparation of the land, its effect on the ultimate state of the soil in tropical and sub-tropical countries amounts to a mixed blessing. It may well be that for such climates a new system of cultivation will arise in which the plough has no such dominating part as it has now. In the meantime the observant farmer will ask himself at each stage of his operations how this or that treatment is likely to affect his particular soil and how he can be guided by necessity and not by tradition in making his decisions.—(*Aust. Sug. J.* 37, p. 95, 1945.)

Recent Work on Cacao Soils in Nigeria

Soils of the "Ilepa" group appear to contain exceptional reserves of fertility, either in the form of incompletely weathered minerals in the soil itself, or of decomposing rock at the depth reached by plant roots. This affords an explanation of the remarkable results of experiments with green manures on Moor Plantation, in which yields are still being maintained after more than twenty years of continuous cropping. Similar green-manuring experiments on the relatively good sedimentary soil at Nkwele (Onitsha) at first appeared to indicate that the fertility of some of the best areas (of a clayey texture) was being maintained, but now, after ten years, a steady fall in yields is occurring.

The "acid-sands" group of soils of Benin and the Eastern Provinces rapidly loses fertility under continuous cultivation. These soils have been derived from very porous sedimentary beds, which have been subjected to intense and prolonged leaching. In nature, a high-forest cover develops, and when first cleared, the soils are highly fertile, but they contain no reserves to replace the losses which inevitably occur if intensive farming is attempted.

The differences between soil types are clearly demonstrated by the results of artificial-manuring experiments involving annual applications of nitrogen, phosphate and potassium, alone and in all combinations. The area used at Moor Plantation did not prove markedly deficient in any of the main plant foods, though superphosphate consistently produced small increases in maize yields. Results at Benin at first showed good responses to all manures, but applications were omitted in the second year, causing very poor yields subsequently. At Nkwele each manure produced a big increase in yields, whilst the effects of the combinations were even greater than the separate effects added together. At Umuahi the main feature was a great response to the combination of artificials on the limed area whereas only farmyard manure showed signs of maintaining yields on the poor unlimed area.

A detailed study of the soils in the neighbourhood of the Ibadan Native Administration Experimental Cacao Farm has been in progress since the end of 1940. The main conclusion reached is that the growth of cacao in the Crystalline-Rock area is not limited by soil fertility, but by the moisture content of the soil that is largely determined by the mechanical composition. The great variations in mechanical composition that occur in this area have been shown to be caused partly by differences in the complex parent rocks, and partly by a "sorting-out" effect related to the natural processes of development of the topography.—(*Soils and Fertilizers* 8, p. 71, 1945.)